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GROUP

CLASSIFICATION

CANADIAN PATENT

LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

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FILED

PRIORITY DATE

No. OF CLAIMS

LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

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Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

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Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential sorew element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screv element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 45, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

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fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft lo.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 rounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein P_c is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A end B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

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approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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I CLAIM:

- 1. A device for expanding a metallic liner inside a conduit which device comprises a shaft element, an expanding die member attached to said shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft to contact said expander member and to maintain said expander member against said liner-forming member, whereby said liner-forming member is urged against said liner by a substantially constant force.
 - 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm members disposed around said shaft and being pivotable outwardly therefrom to contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
 - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 1 4. The device of Claim 3 wherein said compression means comprises
 2 a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a

 sleeve-like element connected to said movable bearing plate member and

 slidably positioned on said shaft and a member connected to said shaft to

 limit the travel of said sleeve-like element.
 - 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said chaft.
 - 7. A device for installing an expanded metallic liner in a conduit which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, each slidably positioned on said shaft and contacting opposite ends of said columns; limiting sleeves attached to each of said bearing plate members and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members outwardly with a substantially constant force.

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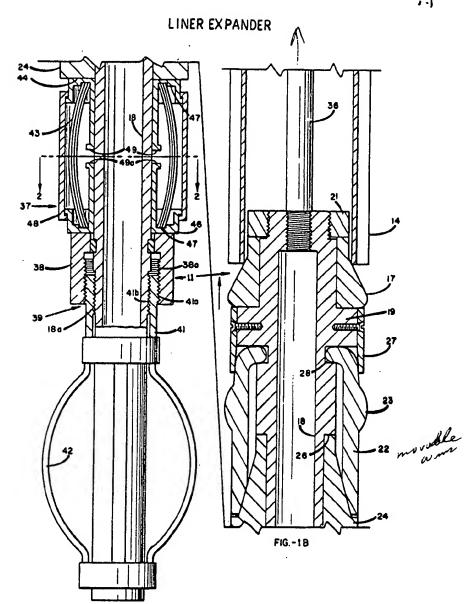
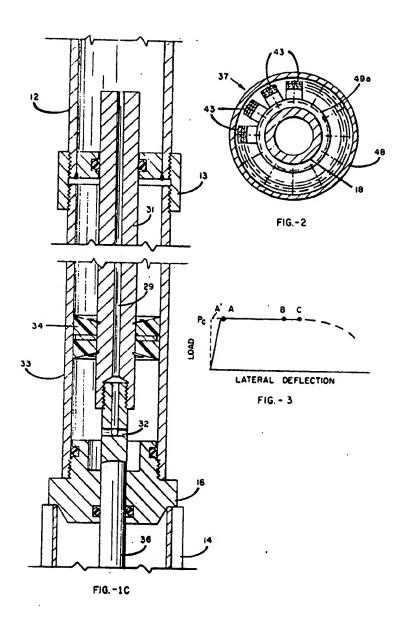


FIG.-1A



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3. A dorios for expending a schallic liner invide a candid which device comprises a sheft element, on expending the moder attended to said sheft closent, which dis member comprising a movelle liner-forming member positioned on said sheft and being cadially movelle in respect thereof to contact said there as expender moment aliably positioned as said sheft between said sheft and said the number to move said liner-forming number from said sheft and a constant force spring member positioned on said sheft and account force spring number to contact said acquasar symbor and to maintain said acquasar sustone against said liner-forming member, starrely said liner-forming number to unyout against said liner-forming member, starrely said liner-forming number to unyout against said liner for a substantially constant force.

E. In a device for installing an expended metallic liner in a combrit wherein an expanding die is moved through a liner positional in said somethis to expend said liners a cylindrical shaft almosts, an expending die mesher attached to said abart, said the sentor comprising a plurality of any numbers disposed around said shaft and being pivotable untearily therefore to contact said liner, a cone mesher alidably positioned on said shaft between said shaft and said any meshers to carp said are numbers consarely frue said shaft, and a constant force opting number positioned on each staff to contact said once number and to what to said are numbers, whereby said are too between smallers, whereby said are too between the constant purces.

3. The device of Claim & wherein said scarbors from expring acober comprises a planship of columns disposed account said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite cols of said columns, at least one of said tearing plate members bring movebly positioned on said what and being in contacts with said come number, stop means commerted to said start to limit the actual travel of said southle bearing plate number along said start, and compression means for uniquining a internal deployation in said columns.

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- 5. The device of Claim 3 wherein said shap means comprises a alsowed like alsowed commented to said would bearing plats number and alignity goal blocks on said shaft and w sunface commented to said shaft to limit the trivial of said alsowed like alsowed.
- 6. The device of that 3 whereis soil column have a nectuapitar cross-section, the width being greater than the thickness, and having the wider face moved to the dissector of said shaft.
- 7. A device for installing at expended estallis liser in a comissis between vertices and perference as the weight from the secretaries where on said shaft, said the senter comprising a planshity of are southern disposed direnthreshially around the extends of eald shaft and being pleotable cetmarkly therefrom to content the liner; a statest expending master slidebly hise ware of exposure are him hos finds hims manufof finds hims no he here outskindly from suid shaft; a plurality of alender columns, cash beving a long reutangular oross-seviion and disposed sireamanentially shout said chaft; an upper bearing plate member and a lower tearing plate member; sech slittally positioned on said short and contacting opposite order of maid me; limiting alsows ubtacked to each of said bearing plate numbers and alidably positional an asid shalt; a shoulder number on send shalt; a differential sever element connecting well shoulder and sold shorts to apply skiling look to easy columns suid thouless being consequents with the sated to entil looks bearing plate mester, whereby the arial trevel of eath bearing plate members in limited; said column weathers breamsitting their bushling load to said arm zembers to urgs said arm greaters criterially with a substantially communications.

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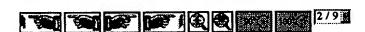
fince tools of the type sentioned above of set are employed in welldeep in the ground, it is highly preferable that a tool be used which under no
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My invention will be better understood by reference to the following description and the measurapping drawings wherein:

Figure 1A, 18 and 1C, taben together, conviltute a partial sectional view of a preferred embodiment of a liner expending tool according to the present investion; and



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Figure 2 to a sectional view of the apparates of Figure 14 taken at

Figure) is a typical plot of applied lock versus believion for the constant force spring device of the Lamantion.

Referring to the drawings, Figure 14 is the bottom portion of a liner expending tool for one in installing a mutable liner in a well, while Figure 13 Ellertrotos tivo middle section of such a tool and Figure 10 represents the upper section of the tool. The expending tool il is attached to standard well tabing 18 by compling 15 and, typically, may be inversed from the surface through a woll easing (not shown) to a point in the nuring at which th is sesired to invivit a metallic liner. Before inserting the tool into the well, an elongated vertically engraphed liner is Cabricated from mild steel, or other suitable miliable meterial, is placed on the tool. The corrupted liner is secured in position by contact at its upper end with a cylindrical shoulder marker 16 and, st the lower and by contact with a first-stage expansing die 17 in the form of a trimonted circular core which serves as a firstmenting die in the second bareinefter described. The expanding die is fixedly edianied to a controlly lossted, elemented evidentrical believ short ld which forms a portion of the body of the tool. As shown, the expending \$10 17 20 is held in place between a lower shoulder 19 and coller 21 threaded onto the short. . A plurality of moveble arms 49, preferably provided with outserelly enlarged portions 25 sear the top; sow disposed in the form of a syllndar around shaft 18. The enlarged purbloss of the arms 23 upon being moved outvarily emisses the liner to perform the final step of expending the unregated limor into a substantially syliminical shape. The are combers ET are pivotally etteched to the sheft so me to be movehile outcomely from the sheft by a tapered expending member 2s aliably positioned on the sheft to serve as a second-stage expender. The surface of the moster Db, as shown, moves upwardly along the shart to sugage with the arms and more than outverfily. Advantageously, the inside surfaces of the same 82 and the outside surface of expanding member 24 fore setting sentions, typically cotegonal is shape. The expension of the arm members is comirabled by the condition of the member 26 rhich moves upwardly





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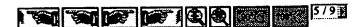


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forces between the tool and the liner and the preserve emerted against the casing are maintained at prenaturalmed eafs levels. The constant force spring
maker assures that the southest preserve between the liner female, portion 25
of the sum: 22 is great enough to previde the Southed Sefermation of the sading, while preventing damnes to the saxing or to the tool.

The equators force spring seasor 77 is alignly nowned on the shart 10 and hald between the expending alsonat 20 and a cylindrical lower obsolder master 35 forcing a purities of a differential serve alsonat 39 which are sent to be about 15 forcing a purities of a differential serve alsonat comprises about member 16 on the outride of which are sent mut threads also not be lower about the human 15 provided with famile threads 35 and thinkle member 15 provided with famile threads 35 and thinkle member 15 provided with famile threads and the inside, respectively, to suppay with threads on the shaft and the shoulder. The two sate of threads are source, such as square, modified equare, or force threads, to withstand very high tends and differ in prich so that shoulder 35 is severed specify on the shart 15 when the shaft is revolved relative to thinkle 12. The shoulder 35 is severed to the shaft 16 by splines 35 so that it can alide implicationally, but it is not tree to rotate on the shaft. Fixedly attached to the lower sent of the thinkle is a friction senter, such as two aprings 12, a aparentically estuated friction past, or other such device for frictionally empaging with the ionide mall of the conjuit to secure the thinkle against thousands with respect to the shaft. Preferably, the direction of the choolidar senter threads 15a to the same as that of the shaft threads 15a, e.g. right-hand threads, and the pitch, or lond, of threads 15a is slightly greater than that of threads 15a, or it is no pitch rottle being alone to unity. In that success, clock-vice revolution of the shaft relative to the thinkle sames shoulder senter 35 to atwance upoure alightly on a compression loud is contracted upon the shaft approximately 7 to conce burning. For example, one vertice according threads on a chart approximately 1.7-inch outside dissector and five and threads increase threads/ison square threads on a shoulder approximately 2.5-inches inside dissector.



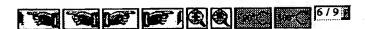


Donatest force spring element 37 comprises union element by, siventageomaly convincing of a plurality of alongsted columns disputed around shuft 18. Upper bearing plate number by in a content with the apper ends of the solumn and is elikably positioned on shaft 18 to transact the force of the spring longitudinally against the bottom and of superdox number of. Lower bearing plate number be confecte the lower ands of the columns and is sorted queuelly along the shaft by langibuliant movement of lower saculder 39 on a result of revolving differential movement 39. Greaves 37 are provided in sach of two bearing plates, to form an upper race and a lower race, into which the code of the columns are inserted. These greaves may be anapad to convers with the shape of the column suchs it sacted. A cover 40 any be

A notes for limiting the defination of the columns is required. Although the column element furnitions in a buckled condition, application of . proceedes accorrective load thereto would sense total failure or repture of the columns. Therefore, a pair of stope by and itse are provided for this purpose. As shown, the stope ere rigidly connected to the bearing plates, and, in effort comprise upper and lower limiting slauves positioned on the sheft to alide longitudinally therems. The ends of the stops may move toward, or ever from, each other so the Lord on the spring number vertes. Lover slaves bys is prevented from moving form by lower shoulder 36 someoted to the short 10. or, the specing between the ends is much as to limit the longitudinal travel of the bearing plate members on they move together to prevent persons deformation of the column almosts by. Wantons alternative means for preventing damage to the column element may also be employed. For example, yield or rings someted on the obest may serve as stops, or the cover 48 provides with suitable commentions may be amployed for this purpose to limit longitudinal and/or lateral seffection of columns.

The columns of the column clement 45 may be arranged eroused the charit 16, which as shown here forces a portion of the body of the spring ferries, with each of the columns fitbed in the races 57. The columns may be

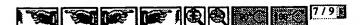
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ritied closely together as shows, or may be spared around the race, with separeters used between them to meisteds the desired spacing. The resolut of construction. For example, the elementers ratio of the column may be warled will depend upon column characteristics and the meiorials of construction. For example, the elementers ratio of the column may be warled widely, say the column make say be round, flat, flows or hanged. The preserved construction is a thin, element column with tousded ands, from to now within the races shaped to the convenient of the column case. Materials which may be satisfactorist; employed for the column are or contained for alloy stands, such as phospher bronze, beryllium support, the high stokel alloys and other similar anterials providing satisfactory semantant properties. Typically, the individual columns are of long rectampliar cross-section, with the ridth being greater than the likehoods, and arranged as that the wider race of the columns is normal to the dimentar of the about. Thus, with scritciant compression loading, the columns backle, and tend shout the sain having the loars consent of inartia, e.g., cutawardly may from the shaft 15.

For example, a group of columns 0.157-inch thick by 0.435-inch wife by 10.625-inches long, with the ands rousend, were febriously from A.I.S.I him observed and drawn at 575°F. Buth column was found to require a critical suppression looking of 350 pounds in order to bunkle the entume. After bunkling, the estumes were found to have a very first spring characteristic, as shown in Figure 3, wherein F₀ is the critical bearing look and point 0 represents the look and deflection at which the stress in the enteress fibers of the delaws exceed the yield point of the saterial. Theoretically, the shape of this apring characteristic ource is described by source 04'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical straing limits, thich, af course, say he varied according to the application for width the spring is designed. For example, where a large number of flexing quies are not enticipated, a vertical strain just below the yield point may be used, value with a great number of flexines, the working stress may be held to less than the enforcess limit of the satural of sonstrain tion. In the above-manifoced teats, the lateral desirection was limited to





approximately one inch, at which the longitudinal defloration was approximately 0.225 inches. From earn deflection to the assisten deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 90 columns, each having a critical buckling load of 1950 younds. The interal deficience was limited between 0 and about 1.00 inches by supropriately positioning the stope. Once compressional loading, the spring element bookled at scheturially 25,000 pounds and from a longitudinal defication of 0.0k issues (making) to stook 0.15 inches the load reasonal substantially at 25,000 pounds.

Or course, in dorigating a spring element as above it in advantagements obtain the greatest possible value of longitudinal defination for specified value of laboral deflection and artical bubling load, while unintending the stress level in the columns at a safe lavel. The preferred columns, therefore, are laminated, as shown in Figures 18 and 2, with writiple flat employs unline to each column.

In the operation of the shows expending tool for setting a liner in well sential, the made-up tool is lovered into the well as sectional shows, with the area 22 in the retreated position. Then the tool is at the desiral level, the well tofing is revolved. The friction member by engages with the wall of the mating and prevents thinkle his tree revolving. With several revolutions of the tables, lower shoulder 15 is nowed againstly by differential server 39 to bushle spring alasment 37 which has a predefending writical bushling loss. This less is transmitted assembly against the lower and of expender 16, and its tapered surface is engaged with the tapered surface on the Latine of the error 21 to args the tape outwardly with a substantially constant force proportional to the critical bushling loss of the spring alasment. Statementally, the expending tool is passed through the liner to expend 10 in the casing in the memor described hereished ore.

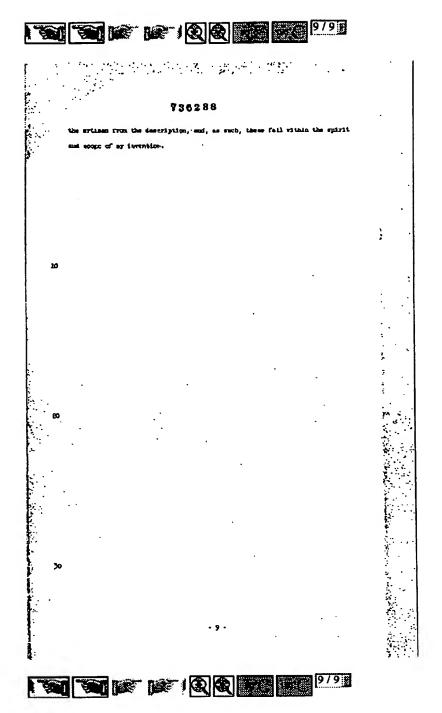
The foregring description of a preferred substitute of my investion.

Let the purpose of examplification. It will be understood that various medifications in the descript of construction will become apparent to

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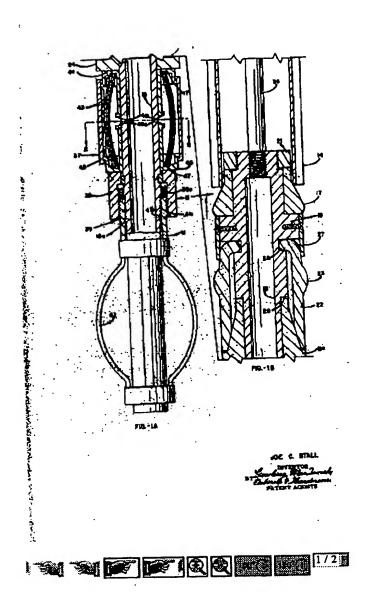
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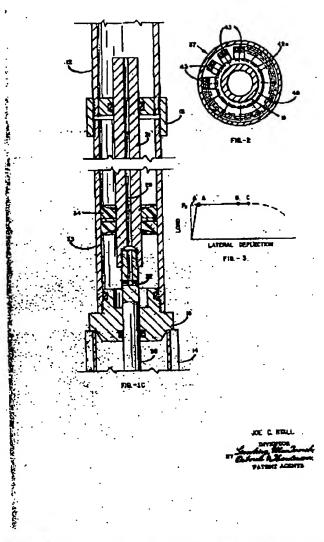


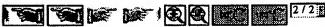


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